

Some Notes on Low-Noise Receive Antennas

Carl Luetzelschwab K9LA May 2016

One of the most important items in a 160-Meter DXer's tool box is a low-noise receive antenna. Sure, you can work many DXCC entities with your normal transmit antenna, but a low-noise receive antenna will open up a new layer of DX. The following are some notes I've collected over the years during my chase for 160-Meter DXCC.

First Some Physics

160-Meters is a tough band. Three physics-related issues make it tough. First, the amount of absorption (loss) incurred by an electromagnetic wave in the ionosphere is inversely proportional to the square of the frequency. As we progress lower in frequency from 28 MHz down to 1.8 MHz, absorption increases significantly. The end result on 160-Meters is a hop with much loss.

Second, the amount of refraction (bending) incurred by an electromagnetic wave when it encounters an electron density gradient is also inversely proportional to the square of the frequency. As we progress lower in frequency from 28 MHz down to 1.8 MHz, the wave bends more and as such does not get as high into the ionosphere. Thus we get shorter hops on 160-Meters. The often-cited 4000 km limit for a single hop is applicable for the high end of our HF region – up at 28 MHz. Down at 1.8 MHz, a 2000 km hop is more the norm (which then leads us to invoke ducting for the extremely long 160-Meters QSOs).

Third, the Earth's magnetic field has a profound effect on propagation through the ionosphere on 1.8 MHz, since the ionosphere is immersed in this magnetic field. The reason is that 160-Meters is close to the electron gyro-frequency (from about 0.7 MHz to 1.7 MHz depending on where you are in the world), which is the frequency at which electrons spiral about magnetic field lines. On our HF bands (80-Meters through 10-Meters), two characteristic waves propagate through the ionosphere similarly in terms of the path taken and absorption – the ordinary wave and the extraordinary wave. Thus both waves arrive at a distant location and offer more probability of a QSO (of course they could also be 180° out of phase and cause fading). But on 160-Meters the extraordinary wave is more heavily attenuated (more loss) than the ordinary wave, leaving us just one wave that arrives at a distant location. Thus polarization could be an important factor.

Noise

There are two types of noise that we're concerned with on 160-Meters – atmospheric noise and man-made noise. Noise propagates just like a desired signal, so during the day man-made noise or very near-by thunderstorms are the problem. During the night, atmospheric noise can propagate in to your QTH from distant thunderstorms. And of course we still have man-made noise – maybe even more than during the day due to nighttime lighting and more people being home.

With the proliferation of electronic devices over the past many years, I'm sure our man-made noise has increased. Which means you have to work hard to try to eliminate as much of this as possible in your own home and in your neighborhood.

My noise on 160-Meters on my inverted-L transmitting antenna on a good winter night is down around -103 dBm in a 500 Hz bandwidth (determined by calibrating the S-meter on my receiver in terms of power in dBm). That translates to around an S3 level assuming S9 is -73 dBm (50 uV) and an S-unit is around 5 dB (which is about what I've measured on several receivers I've owned).

I've always thought that was pretty quiet – until I saw a message from Dave K1WHS on the topband reflector last December. He lives in a rural area in Maine near the New Hampshire border. See Figure 1.



Figure 1 – K1WHS QTH

Using his K3 and P3 panadaptor, he measured -131 dBm in 500 Hz on his vertical during the day, and -122 dBm in 500 Hz on his vertical after sunset. As expected, the amount of noise after sunset increased due to lightning discharges from distant thunderstorms propagating in. Compared to my -103 dBm in 500 Hz at night, K1WHS has an advantage of around 19 dB! I'll bet I could have heard the VKØEK and FT4JA DXpeditions on 160-Meters if my noise was 19 dB lower. I don't know if I would have worked them, but at least I could have tried.

The Concept of Low-Noise Receive Antennas

So what makes an antenna a low-noise receive antenna? In one word, it's "directivity". If you have an isotropic antenna (one that receives signals equally over all azimuths and elevation angles), it receives noise from around the compass – noise that covers up the desired signal. It has no directivity. What does the directivity do? It results in the antenna picking up less noise from around the compass. And that improves the SNR (signal-to-noise ratio), which is the main goal of a low-noise receive antenna.

Verticals in the real-world are close to an isotropic antenna. They are omni-directional in azimuth, but they do have a null in the pattern straight up (along the axis of the wire or tubing) and at low elevation angles. Thus a vertical does have some directivity.

For a good amount of a directivity, think of a Yagi antenna on the higher bands. A well-designed Yagi should have one major lobe, with little response elsewhere. Thus for all intents and purposes it only picks up noise from the major lobe. But noise decreases with increasing frequency, so Yagis on the higher bands are not generally used as low-noise antennas (but they can be) – they’re usually used for the gain that is a result of the directivity. Since building and erecting a Yagi on 160-Meters is tough (it has been done at Radio Arcala OH8X), other “smaller” antenna designs offer directivity to pick up less noise.

The Beverage antenna is probably the most well-known low-noise receive antenna. Since low-noise receive antennas are by definition used only for receive, gain is not an issue as negative gain (loss) can easily be made up with a preamp. There are low-noise antennas that offer good directivity and can be used in receive and in transmit – they have positive gain. The 4-Square is one such antenna.

RDF

The RDF (Receiving Directivity Factor) of an antenna is a measure of the theoretical improvement in signal-to-noise ratio of an antenna. Thus two antennas can be compared to see which one is better.

Unfortunately there’s a problem with this computer-derived parameter when translated to the real-world. The definition of RDF is the ratio (in dB) of the forward-lobe gain of the antenna to the average gain of the antenna in all directions (both azimuth and elevation). Inherent in this definition is the assumption that noise arrives equally from all around the compass. But noise doesn’t arrive from all directions equally. Man-made noise originates from specific locations. And atmospheric noise originates from specific thunderstorm areas.

Thus I believe it is possible to have two different antennas with the same RDF, but they could offer different signal-to-noise ratio improvements depending on the direction of arrival of the noise and where the nulls are in the antenna pattern.

SAL (Shared Apex Loop) vs BOG (Beverage On Ground)

In the fall of 2013 I installed a Shared Apex Loop array to help with my receiving efforts on 160-Meters, 80-Meters and 40-Meters. See my review of it in the April 2014 issue of QST or on my website (<http://k9la.us>) in the “Rcv Antennas” link on the left side of my home page. It opened a new layer of DX for me, and I added a number of new 160-Meter DXCC entities to my totals.

In the spring of 2015 I installed a KD9SV two-direction BOG for additional help on 160-Meters. See my review of it in the September/October 2015 issue of NCJ or on my website (also in the “Rcv Antennas” link).

The following table (Table 1) highlights some of my SNR (signal-to-noise ratio) measurements on W1AW on 1802.5 KHz comparing the transmit inverted-L (RDF about 5 dB), the SAL (RDF about 9 dB) and the BOG (RDF also about 9 dB). I should point out that a calibrated S-meter (in terms of signal power in dBm) must be used to make these measurements.

Date	Time (UTC)	Transmit Inverted-L	SAL-20	RBOG
7 May 2015	0025	5 dB	11 dB	19 dB
7 May 2015	0040	24 dB	33 dB	35 dB
13 May 2015	0020	14 dB	10 dB	12 dB
13 May 2015	0030	9 dB	7 dB	11 dB
4 June 2015	0056	17 dB	21 dB	32 dB

Table 1 – SNR Performance Comparison of My Three Antennas

On three of the five listening periods the SAL had a better SNR than the transmit inverted-L, and the BOG always had a better SNR than the SAL. Note that on 13 May 2015 at 0020 UTC the transmit inverted-L had a better SNR than both the SAL and BOG. I believe this latter observation shows that signal characteristics and noise characteristics can vary in the short term.

With respect to the BOG always beating the SAL, the RDF values quoted in the paragraph above the table suggest that their performance should be equal. But as discussed earlier, noise does not arrive as assumed in the definition of RDF. So why the difference? Let's look at the azimuth and elevation patterns of both antennas (Figure 2).

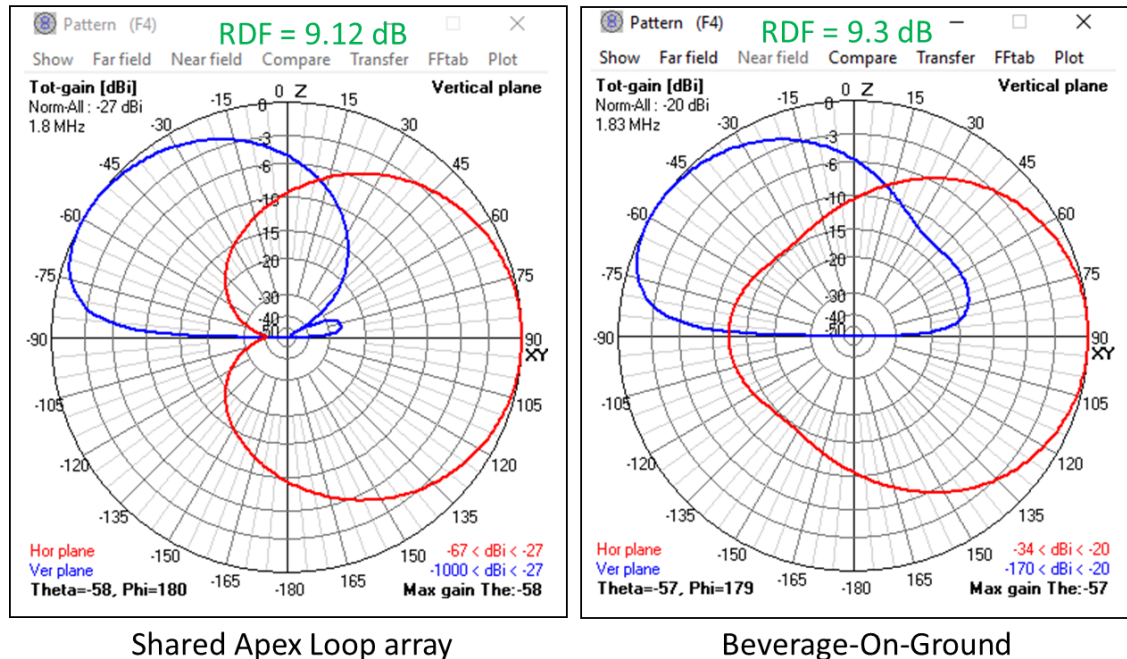


Figure 2 – Patterns of the SAL and BOG

The SAL has a much better null off the rear, but apparently that has nothing to do with the better performance of the BOG. The 3 dB beam width of the SAL azimuth pattern is about 100

degrees, whereas it's about 90 degrees for the BOG. The 3 dB beam width of the SAL elevation pattern is about 69 degrees, whereas it's about 67 degrees for the BOG. Thus the better performance of the BOG over the SAL could be due to picking up less noise off the front (and maybe even the side). This makes sense as I listened to W1AW in the early evenings when noise off the back was minimized due to the back being towards daylight.

Beverage Over Very Good Ground

I've seen reports by others that when they installed a Beverage over very good ground the performance wasn't all that good. Figure 3 shows the elevation and azimuth patterns of a 570 foot Beverage at 4 feet above ground over average ground on the left (relative dielectric constant = 13, conductivity = 0.005 Siemens/meter) and over sea water on the right (relative dielectric constant = 81, conductivity = 5.0 Siemens/meter).

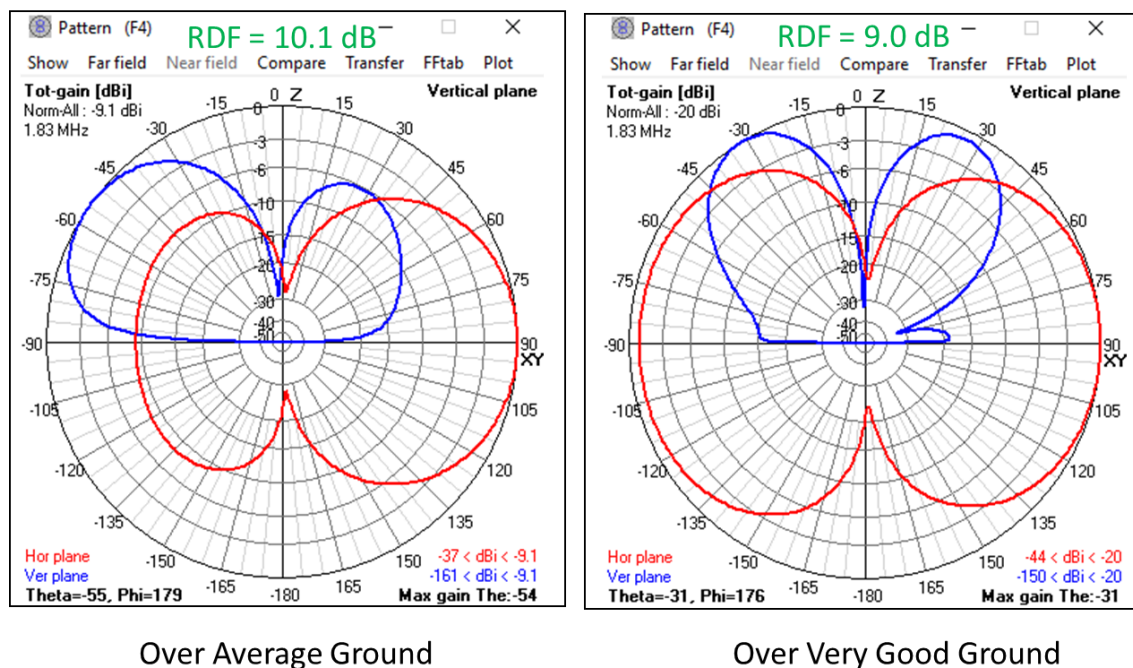


Figure 3 – Patterns vs Ground Characteristics

As can be seen, when the Beverage is installed over very good ground the Front-to-Back ratio degrades, the elevation pattern essentially shoots straight up and the RDF degrades a bit.

The lesson here is that Beverages were meant to be installed over average or even poor ground. Of course this is exactly the opposite of what you want to do for your transmit antenna.

Summary

I hope you enjoyed reading my notes on low-noise receive antennas. Perhaps you can apply some of these lessons to your system.